CLAIMS

1. A multi-layered photobioreactor, comprising:

at least one first culture region containing both a microorganism and a culture medium therein to execute vegetative growth of the microorganism;

at least one second culture region closely layered on a side surface of the first culture region and containing both a culture medium and a microorganism therein to produce a useful metabolite; and

a transparent partition placed between the first and second culture regions to separate the first and second culture regions from each other,

wherein the first and second culture regions are provided in an inside portion and an outside portion of the photobioreactor, respectively, to allow sun light or artificial light irradiated to the photobioreactor for cultivation to sequentially pass through the second culture region and the transparent partition to reach the first culture region; and a plurality of the photobioreactors as unit modules are spatially arranged to produce another photobioreactor.

2. A multi-layered photobioreactor, comprising:

at least one first culture region containing both a microorganism and a culture medium therein to execute

vegetative growth of the microorganism;

at least one second culture region closely layered on a side surface of the first culture region and containing both a culture medium and a microorganism therein to produce a useful metabolite;

a transparent partition placed between the first and second culture regions to separate the first and second culture regions from each other; and

a light irradiation unit to supply light energy to the microorganism in the photobioreactor,

wherein the first culture region is provided to be not in contact with the light irradiation unit, while the second culture region is provided to be in contact with the light irradiation unit, thus allowing the light emitted from the light irradiation unit to sequentially pass through the second culture region and the transparent partition to reach the first culture region; and a plurality of the photobioreactors as unit modules are spatially arranged to produce another photobioreactor.

3. The photobioreactor as set forth in claim 2, wherein the second culture region to produce a useful metabolite is formed at an outmost surface of the photobioreactor, and sunlight is thus irradiated to the second culture region at the outmost surface of the

photobioreactor.

4. The photobioreactor as set forth in claim 2 or 3, wherein the light irradiation unit is one or more selected from the group consisting of fluorescent lamps, halogen lamps, optical fibers, neon tubes and light-emitting diodes.

5. The photobioreactor as set forth in claim 2 or 3, wherein the light irradiation unit comprises a plurality of independent units which are independently operated.

6. The photobioreactor as set forth in claim 1 or 2, wherein the photobioreactor has one shape selected from the group consisting of a rectangular flat-plate shape, a cylindrical shape, a tubular shape and other three-dimensional shapes.

7. The photobioreactor as set forth in claim 1 or 2, further comprising gas injection unit to inject gas into the first and second culture regions.

8. The photobioreactor as set forth in claim 1 or 2, wherein an impeller or a magnetic stirrer for mechanical agitation is placed in the first and second

culture regions.

9. The photobioreactor as set forth in any one of claims 1, 2 and 6 wherein the photobioreactor is arranged in a one-dimensional, two-dimensional or three-dimensional consecutive arrangement.

10. The photobioreactor as set forth in claim 1 or 2, wherein the photobioreactor is operated in a batch, continuous or fed-batch culture.

11. The photobioreactor as set forth in claim 1 or 2, wherein the photobioreactor is equipped with a temperature control unit and a sun screen unit.

12. The photobioreactor as set forth in claim 11, wherein the temperature control unit is a heat exchanger, a thermostatic circulator or a spray.

13. A method of culturing a photosynthetic microorganism, comprising:

injecting a photosynthetic microorganism to a first culture region to execute vegetative cell growth and a second culture region to produce a useful metabolite, wherein the first and second culture regions are equipped in the photobioreactor of claim 1 or 2

(step 1);

irradiating light to the second culture region to proliferate the photosynthetic microorganism (step 2); and

harvesting the cultured photosynthetic microorganism from the first and second culture regions (step 3).

14. A method of culturing a photosynthetic microorganism, comprising:

transferring a photosynthetic microorganism grown in a first culture region to execute vegetative cell growth by a batch culture to a second culture region to produce a useful metabolite, wherein the first and second culture regions are equipped in the photobioreactor of claim 1 or 2, and injecting newly subcultured cells of the photosynthetic microorganism into the first culture region (step 1);

irradiating light to the second culture region to proliferate the photosynthetic microorganism and accumulate the useful metabolite (step 2); and

harvesting the photosynthetic microorganism from the second culture region and repeating the steps 2 and 3 by transferring all or a portion of the photosynthetic microorganism grown in the first culture region to the second culture region (step 3).

15. A method of culturing a photosynthetic microorganism using the photobioreactor of claim 1 or 2, comprising selectively supplying to the first or second culture region of the photobioreactor a nutrient that has been exhausted with time upon cultivation using the photobioreactor.

16. The method as set forth in claim 13 or 14, wherein, at the step 2, the light is initially supplied at an intensity capable of forming an optimal condition for the vegetative growth of the photosynthetic microorganism until the photosynthetic microorganism reaches a stationary phase, and then is supplied at an intensity capable of forming a stressed condition for production of the useful metabolite.

17. The method as set forth in claim 14, wherein, at the step 3, the photosynthetic microorganism is transported by a peristaltic pump or air pressure.

18. The method as set forth in claim 14, wherein, at the step 4, the light is controlled to an intensity capable of forming a stressed condition for the production of the useful metabolite.

19. The method as set forth in claim 13, wherein the photosynthetic microorganism is selected from the group consisting of *Haematococcus* sp., *Dunaliella* sp., *Chlorococcum* sp., *Chlorella* sp., *Acetabularia* sp., *Microcystis* sp., *Nostoc* sp., and *Oscillatoria* sp.